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MENTAL INFLUENCE ON PHYSIOLOGICAL COST

FOR A RESTRICTED MUSCLE GROUP OF THE RIGHT FOREARM

A THESIS

Presented to

the Faculty of the Graduate Division

by

Larry Ray Johnson

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SUMMARY

This study examines the hypothesis that the physiological effort exerted by a subject, as measured by his muscular tension, depends on his anticipated effort. Furthermore, it examined the hypothesis that the slope of the regression line relating the muscle tension to the weight supported by the subject would remain constant from day to day. The muscle action potential was used as a dependent measure of the muscle tension.

The experiment was restricted to typical laboratory simulation of work, with four male college students as subjects. The static work task was the holding of weights varying from 1500 grams to 4100 grams. Five separate tasks, of at least 16 trials, were performed on each of the four subjects. In all trials, a screen was placed between the subject and the task-weight. A visual display card was used to inform the subject of the value of the weight.

For two of the tasks, the muscle action potential was plotted as a function of the weight supported by the subject. The slopes from the two regression lines were statistically tested with the "t" test to determine if they were equal. On the basis of this test, it was concluded that the slope of the regression line may change from day to day.

In the remaining three tasks, the subject was led to believe that he would support the same weight for all sixteen trials. However, on eight of the sixteen trials, a weight five per cent less than that which the subject expected was presented. From the data thus obtained the mean

muscle action potential for the false weight was tested statistically with a "t" test to determine if it was equal to the mean muscle action potential for the true weight. The result would indicate that they were equal, i.e., the physiological effort exerted by the subject depends upon his anticipated effort. However, when the data for this test were analyzed by means of an Operating Characteristic Curve, it was found that the number of observations was insufficient to find a difference even if it did exist. Hence, no valid conclusion could be drawn about the hypothesis.

CHAPTER I

INTRODUCTION

The advancement of man has been greatly influenced by his understanding and utilization of energy. His natural curiosity has led him into the study of almost every form of energy. Yet comparatively little information has been recorded about one of the most widely used forms of energy, human energy.

The basic chemical and mechanical processes involved in the release of energy from the working muscle are fairly well understood. However, the capacity of a person to exert a voluntary force may be influenced by psychological factors as well as physiological factors. Thus, an effective study of a working muscle should consider both of these factors.

The first problem in a study of this kind is selecting the method of measuring the physiological cost* of the work.

An early attempt at a solution of this problem was the utilization of the Douglas Bag, a device which measures the oxygen consumed by a man as he works. With the arrival of more accurate measuring techniques, e.g., electronic equipment, better laboratory procedures which permitted measurement of the physiological changes of the body during work were devised. For example, changes in heart rate, blood pressure, body temperature, skin resistance (G S R), and muscle tension have all been used as indices of work. None of these techniques is adequate in every case,

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*"Physiological cost" is defined as the decrease in human energy.

however, and their use should depend upon the specific circumstances encountered by the experimenter.

The second problem encountered by scientists in this field is the influence of the subjects' attitude and motivation on his work performance. For example, Poffenberger (9) has demonstrated in two laboratory experiments that the subjective judgment of a subject can influence his ability to perform a task. The first of these is the well known size-weight illusion, whereby a subject lifts, one at a time, two objects similar in all physical respects except size. A significant number of subjects will judge the smaller of the two to be heavier, even though they weigh the same. In this experiment, the subject had involuntarily adjusted his physical effort to the anticipated task demand.

Poffenberger's second experiment involved the use of a dynamometer. When a subject was told to squeeze a hand-grip dynamometer with as much force as possible, he could apply a force of 68 kilograms. However, when the subject was told to repeat the task 45 times, he could apply only 52 kilograms of force. Again, the subject had involuntarily adjusted his physical effort to the expected task requirements. The effect of mental influence on the physiological effort is the basic problem studied in this thesis.

The primary hypothesis to be tested in this study can be stated as follows: The physiological effort exerted by a subject, as measured by his muscular tension, depends upon his anticipated effort. The muscle action potential will be used as a dependent measure of the muscle tension.

The muscle action potential is known to be a function of the force exerted by the muscle, hence the regression line relating these two quantities can be obtained by experimental procedures. From the work done previously in this field by other investigators, this muscle action potential curve is linear for the range of zero to six kilograms and is expected to intercept the muscle action potential ordinate axis at the "rest level" potential. Any deviation from this intercept in the absence of fatigue, should be due to experimental error.

It is of interest to the industrial engineer to know if the slope of an individual's muscle action potential curve varies over time. If the slope is constant, then the function relating force and the muscle action potential could be treated as a steady-state condition. Thus, a secondary hypothesis to be tested in this thesis can be stated as follows: The slope of the regression line relating muscle action potential and the force exerted by the muscle does not vary over time.

This experiment will be restricted to typical laboratory simulation of work, with four male college students as subjects. The static work task will be the holding of weights varying from 1500 grams to 4100 grams.

CHAPTER II

SURVEY OF LITERATURE

A. Physiological Factors.--The relationship between the muscle action potential developed and the force exerted by the muscle has been found, by a number of investigators, to be essentially linear in the range of small muscular contractions.

J. F. Davis, (2) in a manual on surface electromyography, noted that in the range of very strong muscle contraction (six kilograms or more) the muscle action potential, as a function of the pull on a dynamometer, tended to be more exponential than linear. However, below six kilograms, it appeared to be linear. A further study was made to check the linearity with very small loads (zero to two kilograms). In this case, the function was linear.

Lippold (7) measured the muscle action potential in the calf muscle of the right leg as a function of the force applied by the sole of the foot. He concluded that " ...there exists a linear relationship between the integrated electromyogram and the tension produced by a voluntary isometric contraction in the human muscle."

Finally, Inman, et al., (5) concluded that " ...the integrated electromyogram parallels tension in human muscles contracting isometrically."

One point which is common to all studies in this field is the amount of variation that exists both between subjects and for the same subject on two different days. J. F. Davis (2) states, "In the ...dynamometer study, one subject may have produced EMG potentials double or treble those of a second subject for the same pull."

Many factors enter into this variation, a few of which have been studied extensively.

a. Age: R. C. Davis (3) studied the relationship between adults and children and concluded that excitation of the active member increases as a function of the weight lifted, but the level of activity is always much greater for children than for adults performing the same work.

b. Sex: J. F. Davis (2) notes in his manual that " ...the female group average yielded a muscle action potential curve about 50 per cent higher than the male group average in the range of strong muscle pulls."

c. Remote Muscles: R. C. Davis (3) found that the action potential in the passive muscles is increased as a function of the force exerted by the active muscles, and the level of activity in these muscles is a function of the distance they are from the active muscle.

d. Other Physiological Factors: J. F. Davis (2) presents a list of factors which influence the level of activity of a muscle. This list includes:

1. Type of Muscle Tissue (smooth or striated)
2. Use of Muscle (postural or otherwise)
3. Size of Muscle (normal, atrophic, hypertrophic)
4. Degree of Fatigue Present
5. Number of Muscle Fibers per Bundle
6. Number of Muscle Bundles
7. Oxygenation, Metabolism, Bloodflow

B. Psychological Factors.--Psychologists have studied the effects of certain psychological activities on the muscle tension of the individual. Such activities as mental work (10), talking and listening (11), and competition (1) may cause a measurable increase in muscle action potential in the voluntary muscles. Two psychological factors included in this experiment, and of more immediate interest, are imagination and judgment.

Jacobson (6) reports on a series of experiments involving the measurement of muscle action potential of subjects engaged in imagining. When the subjects imagined lifting a weight with their right arm, there was a measurable increase in activity of the muscles which would have been affected by the act. All other muscles in the body remained at their rest level activity. On the assumption that tension is always associated with actual contraction, a lever system was devised which would amplify any movement of the arm. Results showed that actual contraction, on a microscopic scale, accompanied the imagining, even though the subject had been told to remain completely relaxed.

If two weights are to be compared by lifting with the same body member, the standard and comparison stimuli must be separated by a time interval. The result of this time separation is manifested by a relatively large number of "heavier" judgments, even when the comparison weight is equal to or lighter than the standard weight. This is called the "time error" of comparative judgment.

Payne and Davis (8) tested the effect of this time error on the muscle tension by determining the muscle action potential as a function of the proportion of "heavier" judgments. They found that when the proportion of "heavier" judgments was greater than would be expected by chance, the ratio of the muscle action potential developed by the comparison weight to the muscle action potential developed by the standard weight, the C/S ratio, was greater than 1.00. Likewise, when the proportion of "lighter" judgments was greater than would be expected by chance, the C/S ratio was less than 1.00.

Freeman and Sharp (4) studied the relationship of the time error (as measured by the proportion of "heavier" judgments greater than chance) and of the C/S ratio as a function of the length of time between stimuli. They found that the time error curve and the C/S curve paralleled each other and were cyclic in character.

Thus, in both of the above experiments, where the subject is forced to make a choice, the muscle action potential is related to subjective judgment more than to the actual mechanical force.

CHAPTER III

EXPERIMENTAL PROCEDURE

Five separate tasks, of at least sixteen trials, were performed on each of the four subjects. The first and last tasks were controls for defining the muscle action potential curve. The middle three tasks were to determine the effect of the subjects' anticipation of the required exertion on the output level of the muscle tension. The procedures for applying the electrodes, obtaining the desired anticipation of effort on the part of each subject, and analyzing the myograph output to obtain the muscle action potential were the same for all subjects in all tests, and will be discussed in later sections.

A. The Muscle Action Potential Curve.--The muscle action potential curve on the first and fifth tasks were obtained by measuring the muscle action potential as the subject supported different weights. The weights, listed in Table 1, were presented to the subject, one at a time, in the order of increasing magnitude.

Table 1

Weights Used in Tasks 1 and 5

1500 gm	2400 gm	3400 gm
1600 gm	2600 gm	3600 gm
1800 gm	2800 gm	3800 gm
1900* gm	3000 gm	4000 gm
2000 gm	3100 gm	4100 gm
2200 gm	3200 gm	

* Used only in task five

The muscle action potential obtained for each subject from each of the above weights was plotted as a function of the weight. The correlation coefficient and the least squares regression line were calculated for the resulting eight scatter diagrams; i.e., four subjects times two tasks. With this information, the following relationships were statistically tested:

1. To determine the degree of relationship between the muscle action potential and the weight supported.

H_o: $\rho = 0$, where ρ is the true correlation coefficient.

2. To determine the amount of experimental error.

H_o: $A = 0$, where A is the intercept constant in the true regression line.

These relationships permitted testing of the secondary hypothesis, i.e., the slope of the muscle action potential regression line does not vary from day to day.

H_o: $B_1 = B_5$, where B_1 is the slope of the true regression line for task 1, and B_5 is the slope of the true regression line for task 5.

Finally, the muscle action potential from all subjects in both control tasks were averaged and plotted as a function of the weight supported to obtain the grand estimate of parameters for the test.

B. Effect of the Anticipated Effort.--In all trials, a screen was placed between the subject and the task-weight. A visual display card was used to inform the subject of his expected task.

The subjects were told that the purpose of the middle three tasks was to evaluate variability of the muscle action potential for three different loads. These loads were at the 2000 gm, 3000 gm and 4000 gm level, each constituting a different task level. A weight was presented to a subject sixteen times in the same task of one hour duration, and for statistical purposes, the order in which the three weights were presented was randomized among tasks. The order of task assignments for each subject is presented in Table 2.

Table 2

Order of Presentation of Weights

Subject	Task 2	Task 3	Task 4
1	2000 gm	4000 gm	3000 gm
2	2000 gm	3000 gm	4000 gm
3	4000 gm	3000 gm	2000 gm
4	3000 gm	2000 gm	4000 gm

On eight of the sixteen trials, a weight five per cent less than that which the subject expected was presented. This deception was to provide an opportunity for the subject to falsely anticipate the necessary effort for the trial(s). These eight true and eight false weights were presented randomly within each of the three task levels.

From the resulting data, the following equality was statistically tested by the "F" test.

H_0: $\sigma_Y^2 = \sigma_X^2$, where σ_Y^2 is the true variance for the standard weight, and σ_X^2 is the true variance for the false weight.

This relationship permitted direct testing of the hypothesis that the physiological effort exerted by the subject depends upon his anticipated effort.

H_0: $\mu_Y = \mu_X$, where μ_Y is the mean muscle action potential for the true weight and μ_X is the mean muscle action potential for the false weight.

A third point of interest was if the variances for each subject were homogeneous over time. Bartlett's test for homogeneity of variances was used to evaluate this equality.

H_0: $\sigma_2^2 = \sigma_3^2 = \sigma_4^2$, where σ_2^2 is the true variance for the 2000 gm weight, σ_3^2 the true variance for the 3000 gm weight and σ_4^2 the true variance for the 4000 gm weight.

C. Equipment.--The major pieces of equipment used and the source of manufacture are shown below.

Equipment	Source
Power Supply	Sanborn Model 150-400
Recorder	Sanborn Model 154-100 B
ECG Preamplifier	Sanborn Model 150-1600
EEG/ECG Preamplifier	Sanborn Model 55
Table	Special

Photographs of the table and the equipment are shown in Figures 1 and 2.

D. Laboratory Technique.--Prior to the first task, the subjects were familiarized with the test equipment, given a preliminary learning task, and permitted to ask questions concerning the experiment. The typical question was, "What are you to find out?" A typical answer was, "To find statistical parameters for the muscle action potential curve." They also expressed considerable curiosity about the equipment.

Three electrodes were attached to the right arm of the subject for each task. Two active electrodes were placed two inches apart over the

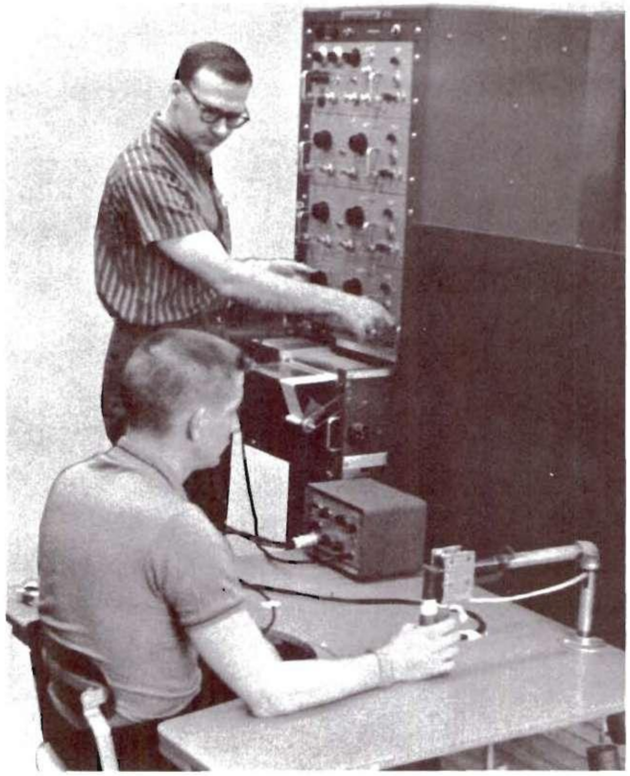

Figure 1. Experimental Area and Equipment

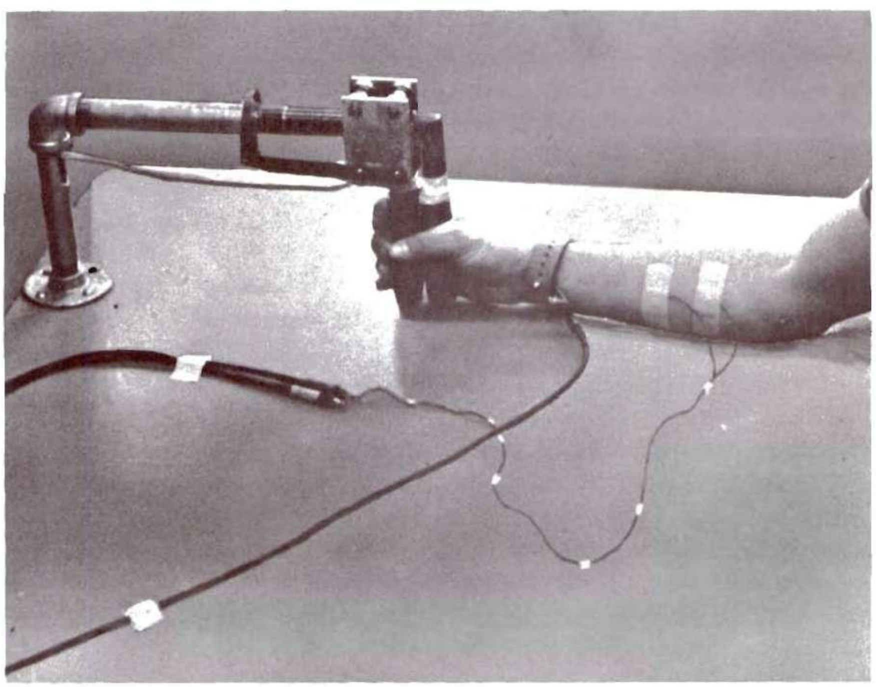

Figure 2. Hand Ergometer

forearm flexor muscle as described by J. F. Davis (2). The third, or ground electrode was attached to the wrist.

The method of attaching the electrode was critical, for if this operation were improperly done, several types of artifacts could result. The electrode method used in these experiments required six important steps, which are illustrated in Figure 3. These steps can be explained as follows:

One, the electrode placement regions of the arm were located and cleaned. The first region was one-third of the distance between the medial humeral epicondyle and the styloid process of the radius. The second region was located two inches further along this same line. These regions were cleaned thoroughly with a solution of ether and acetone (1 to 1 solution) to remove the oil from the skin and as much loose or dead skin cells as possible.

Two, a piece of adhesive tape was placed on the arm at the location of each of the two active electrodes. This tape was approximately 1 inch by 2 1/2 inches, with a 1/4 inch diameter hole punched in the center. A third piece of tape, of nominal size, was placed between these to prevent a conducting bridge of jelly from forming on the surface of the skin while massaging it with electrode jelly.

Three, the skin was massaged through the hole in the tape with the electrode jelly. This massaging action forced the jelly into the pores of the skin and lowered the electrical resistance.

Four, two silver electrodes, 1/4 inch in diameter, were placed in contact with the skin, as permitted by the holes in the adhesive tape. A sponge, 1/2 inch by 1/2 inch by 1/8 inch, saturated with commercial elec-

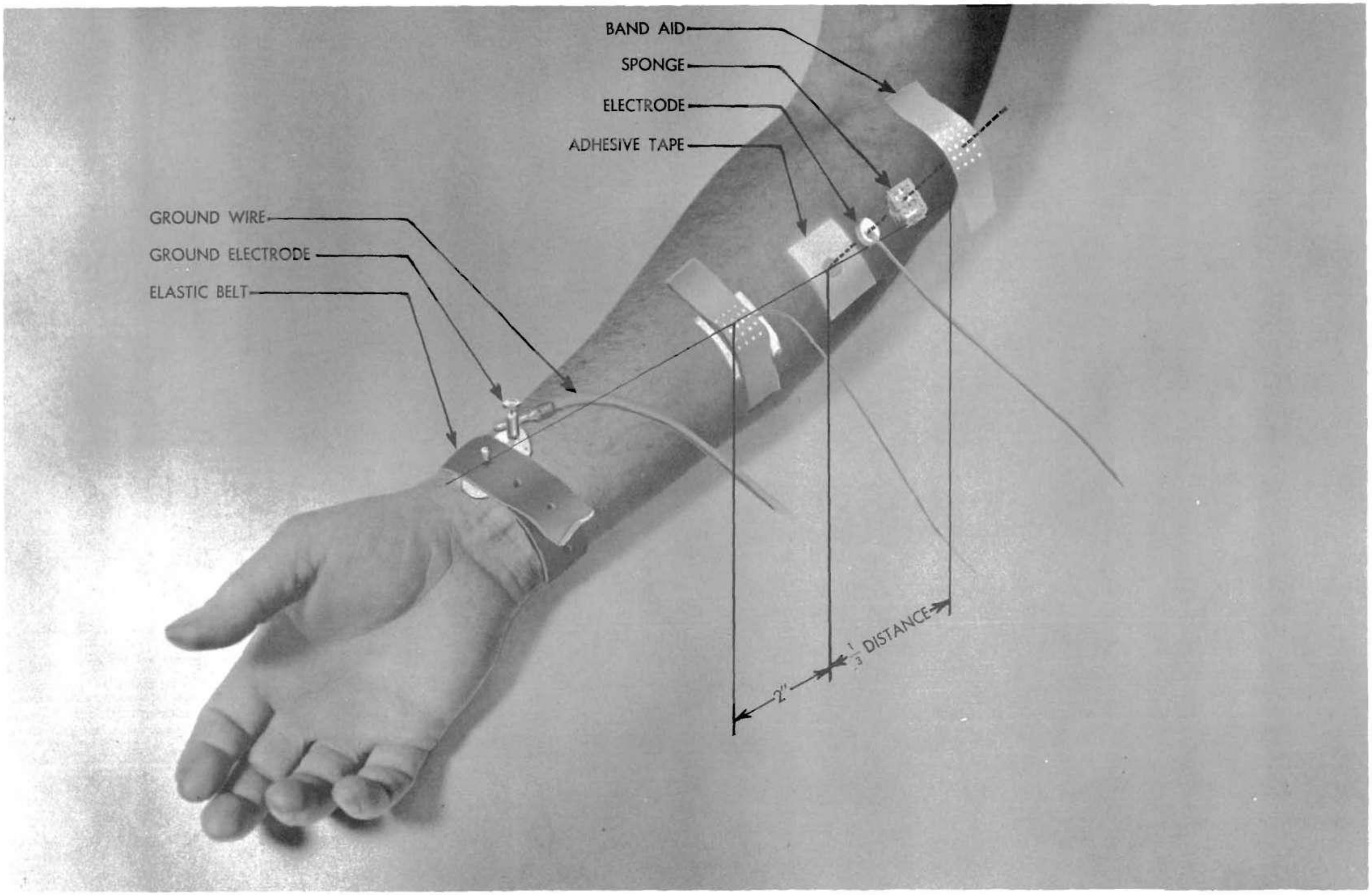

Figure 3. Location and Construction of Electrodes

trode jelly, was placed on top of each electrode. The purpose of the sponge was twofold. First, it prevented the jelly under the electrode from rapidly drying, and second, it provided a uniform pressure surface to hold the electrode firmly in place.

Five, a standard band aid was placed over the sponge, holding it firmly in position. The center piece of tape was then removed.

Six, the electrode resistance was measured to make certain that good electrical contact had been made with the skin.

The skin for the third-ground electrode was cleaned and massaged as before. The electrode was then attached directly to the skin, at the wrist, with an elastic strap.

The output voltage of the EMG was recorded in Micro-Volts on thermosensitive tape traveling at 1 mm/sec. Each of the sixteen work trials for each task followed the same repetitive 32 minute schedule of alternating work and rest periods:

Rest - 90 seconds

Work - 30 seconds

Rest - 90 seconds

The recorded data were analyzed by measuring the ten successive maximum peak-to-peak amplitude of the output voltage at one second intervals. Two samples were taken from each work-rest cycle, one for a ten second interval immediately preceding work and a second sample during the middle ten seconds of work. By subtracting the former from the latter, the increase in muscular activity was obtained for that particular trial.

CHAPTER IV

RESULTS

<u>A. The Muscle Action Potential Curve</u>.--A linear function of muscle action potential and work level was found for the pooled data of tasks 1 and 5 for all significant results. This relationship, shown in Figure 4, had a correlation coefficient, r, of 0.91 which is significantly different from zero at the 0.1 per cent level of significance.

In general, the relationship of muscle action potential to work level was not as strong for the individual tasks. The correlation coefficients for all subjects in both tasks are presented in Table 3. Two values, indicated by the asterices, were found not to be significantly different from zero. Therefore, the data from these two tasks were not used in any computations.

Table 3

Individual Correlation Coefficients for Tasks 1 and 5

Subject	Task 1	Task 5
1	0.88	0.25*
2	0.96	0.88
3	0.81	0.81
4	0.71	0.25*

* Values not significantly different from zero at the 5% level.

The intercept constants in the regression equations computed for each subject in task 1 were tested to determine if they were significantly

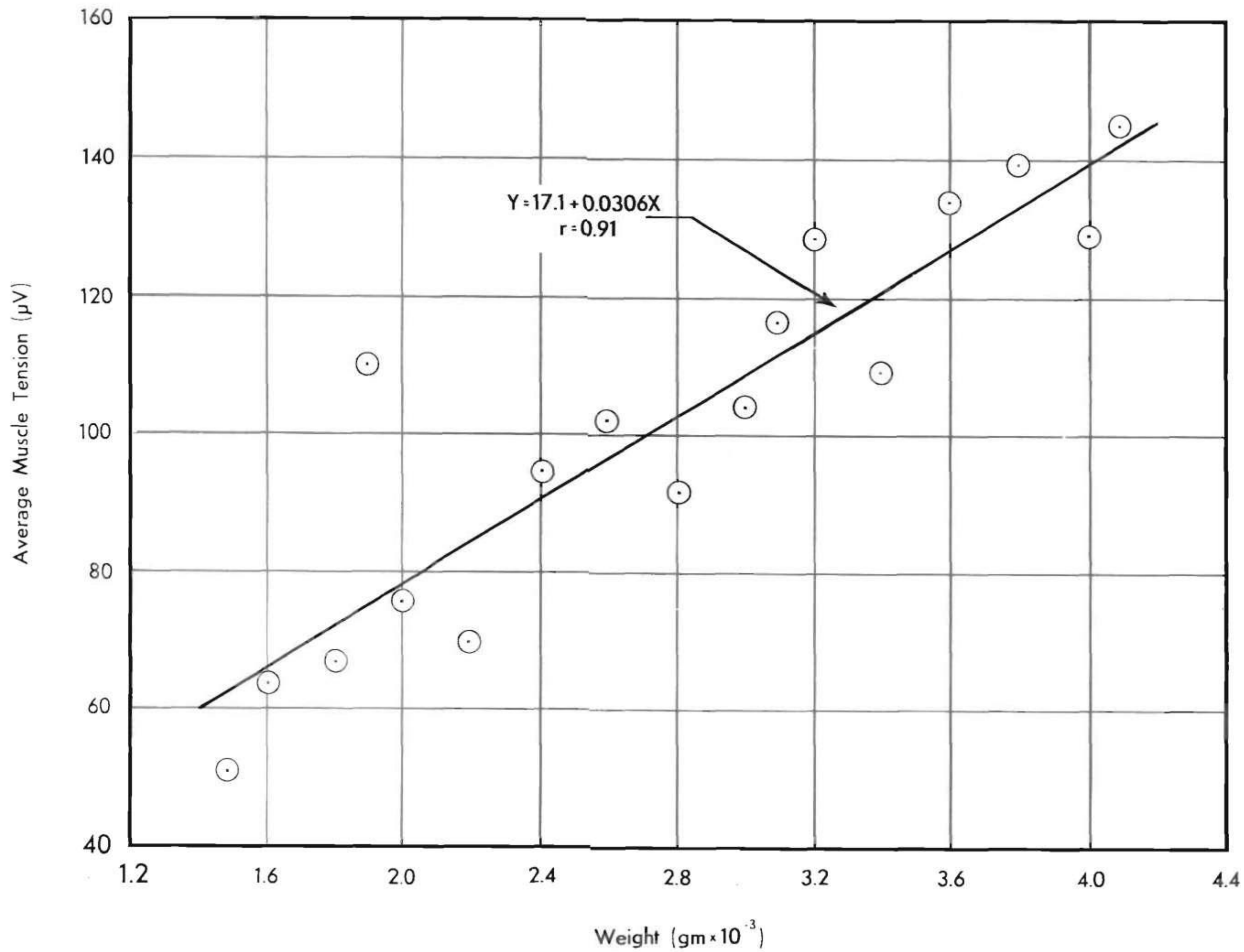

Figure 4.

General Relationship Between Average Muscle Tension and Weight different from zero. In all cases, it was found they were not, and this lack of deviation of the intercept constant from zero indicates the absence of gross experimental error.

Finally, the slope in the least squares equation for each subject in task 5 was tested to determine if it was significantly different from the slope in task 1. Only two "t" tests were made for subjects two and three, since subjects one and four were out of control. The test results indicate that the slope may change from day to day; see Table 4.

Table 4

Variation of Slope over Time

Subject	Slope Task 1	Slope Task 5
1	0.051	
2	0.020	0.025*
3	0.040	0.051
4	0.009	

* Significant at the 5% level.

B. Effect of the Anticipated Effort.--The individual averages for tasks 2, 3 and 4, are tabulated in Table 5. "F" and "t" values are calculated for the standard deviations and averages, respectively, in each of the twelve tasks, i.e., four subjects times three tasks. The values shown in Table 6, indicated only two "t" values and one "F" value were significant at the five per cent level.

Bartlett's test of homogeneity of variances was used to determine if the variances for each subject were homegeneous in all three tasks.

The results indicate that, for two subjects, the variance changed from day to day (see Appendix, part 4).

Finally, the coefficient of variation was computed for each subject in each task using the muscle action potential from the standard weight to determine whether there was a constant relationship between the mean muscle action potential and the standard deviation. This number, however, varied as much as 89 per cent between subjects in the same task and as much as 65 per cent for the same subject between tasks (see Appendix, part 5). These results would indicate that this relationship was not constant.

Table 5

Summary of Average Values for Tasks 2, 3 and 4

	Task 2				Task 3				Task 4			
	1900 gm		2000 gm		2850 gm		3000 gm		3800 gm		4000 gm	
Subject	$\bar{X}$	σ_x	$\bar{Y}$	σ_Y	$\bar{X}$	σ_x	$\bar{Y}$	σ_Y	$\bar{X}$	σ_x	$\bar{Y}$	σ_Y
1	67.4	18.5	73.3	13.6	98.2	18.0	111.6	29.5	99.4	17.8	99.9	21.5
2	54.4	10.9	56.1	19.8	56.3	22.9	48.9	12.8	94.2	9.1	111.1	25.0
3	108.3	18.4	115.8	16.5	161.0	54.0	163.0	36.0	101.0	5.5	104.0	6.9
4	29.2	46.0	37.5	56.0	16.0	14.8	9.8	14.5	20.0	14.6	31.0	8.7

Table 6

Summary of "F" and "t" Values for Tasks 2, 3, and 4

Subject	Test	Task 2	Task 3	Task 4
1	F	1.86	2.27	1.56
	t	0.725	1.101	0.047
2	F	3.33	3.20	4.37
	t	0.219	-0.789	1.796*
3	F	1.25	1.46	1.77
	t	0.572	0.101	0.093
4	F	1.45	1.05	5.79*
	t	0.183	-0.86	1.93*

* Significant at the 5% level.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

As expected, there existed a linear relationship between the force exerted by a muscle and the muscle action potential developed. This agrees with the work of other experimenters cited previously. For the two subjects (one and four) at task five, which did not yield a high correlation, it is apparent that some uncontrolled factor or factors influenced the data. Since a relationship could not be shown to exist, these data were assumed to be out of control and were not used in any of the subsequent significance tests.

It was hypothesized in the introduction that the slope would remain constant from day to day. This hypothesis was rejected. Thus, whenever this method of measuring work is used, the instruments must be calibrated by obtaining the muscle action potential reference curve for each task day. Without this reference, the magnitude of the task force cannot be predicted from the magnitude of the muscle action potential.

The one factor which dominated the experimental results was the in-day variation. Not only was this variation large, but it changed from day to day, as was established by Bartlett's test. The net result was an inconclusive evaluation of the primary hypothesis. This can best be demonstrated by considering the Operating Characteristic curve shown in Figure 5 (curve A), which was computed for $\sigma = 9$, corresponding to the smallest standard deviation found in this experiment.

A change in weight of 100 grams would cause the muscle action potential to change only three units, as indicated by the least squares equation in Figure 4. With a sample size of eight, the probability of accepting a null hypothesis that there would not be found a significant difference between the two samples is 0.76. For changes caused by differences of 150 grams and 200 grams, the probability would be 0.60 and 0.40 respectively. Hence, even if the anticipated effort had no influence on the muscle action potential, it is not likely a significant difference would be found.

To avoid the inconclusive evaluation of the hypothesis, it would have been necessary to increase the size of the sample. For example, if it were desired to accept the null hypothesis stated above with a probability of 0.10 when the change of weight was 100 grams, a sample of 77 observations would be necessary. The Operating Characteristic curve for this size sample is shown as curve B in Figure 5.

It is recommended that in any future experiments in this field, an adequate sample size be selected to assure either acceptance or rejection of the proposed hypothesis.

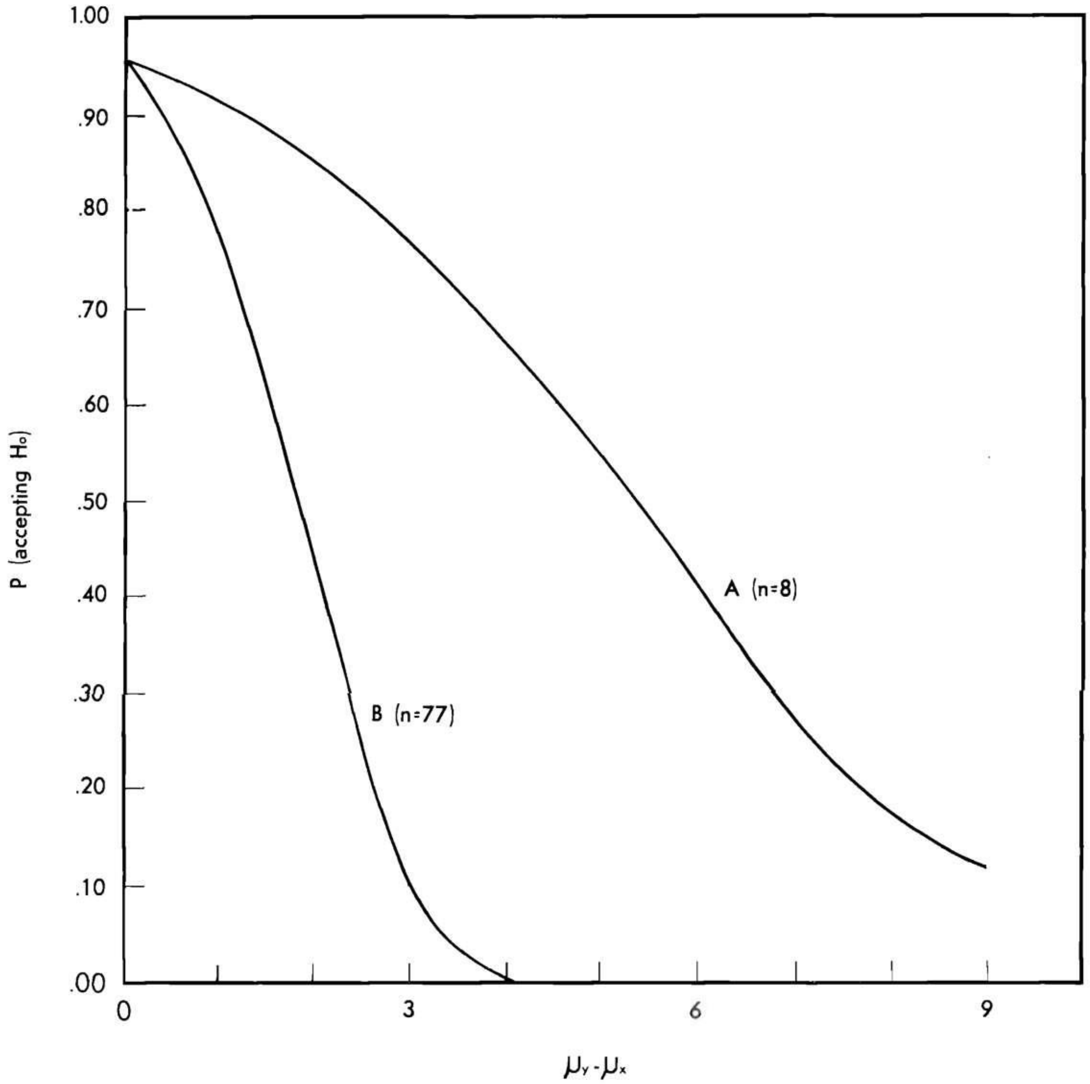

Figure 5

Operating Characteristic Curves For σ=9

APPENDIX

PART I

MUSCLE ACTION POTENTIALS (μ v) FOR DIFFERENT WEIGHTS

	SUBJECT								
	1		2		3		4		
WEIGHT	TASK 1	TASK 5	TASK 1	TASK 5	TASK 1	TASK 5	TASK 1	TASK 5	AVERAGE
1500	149	138	21	37	28	73	9	27	51
1600	91	221	20	43	74	157	--	36	64
1800	96	239	27	62	67	142	10	36	67
1900	--	105	--	74	--	145	--	81	110
2000	97	153	32	72	92	160	4	27	76
2200	105	199	39	62	79	112	20	33	70
2400	152	168	47	84	109	150	14	19	94
2600	146	158	41	90	139	179	17	31	102
2800	158	101	42	87	126	121	12	36	91
3000	143	201	53	110	152	146	20	70	104
3100	187	188	57	84	172	201	-1	62	117
3200	214	271	62	97	162	212	23	36	128
3400	199	267	55	80	122	173	25	39	109
3600	223	280	63	104	122	262	27	60	134
3800	203	150	67	102	156	273	32	37	139
4000	198	224	70	124	146	215	22	56	129
4100	246	144	77	113	157	243	35	40	145

PART II

LEAST SQUARE EQUATIONS, TASKS 1 AND 5

Subject	Task	Least Squares Equation
1	1	$Y = 19.2 + 0.051X$
	5 *	
2	1	$Y = -8.1 + 0.020X$
	5	$Y = 14.9 + 0.025X$
3	1	$Y = 6.2 + 0.040X$
	5	$Y = 33.5 + 0.051X$
4	1	$Y = -7.2 + 0.009X$
	5 *	

* Correlation Coefficient Indicated No Relationship Existed.

PART III A.

MUSCLE ACTION POTENIALS (μ v) FROM TASKS 2, 3 AND 4

Subject 1

Trial	Task 2		Task 3		Task 4	
	1900	2000	2750	3000	3800	4000
1	49.0	56.0	86.6	58.2	65.0	62.8
2	40.0	65.0	129.2	74.6	98.4	101.6
3	46.0	90.0	89.2	130.0	98.8	80.0
4	69.0	73.0	117.6	126.0	119.6	119.6
5	83.0	82.0	84.4	138.8	109.2	109.6
6	77.0	85.0	84.0	124.8	85.6	94.8
7	107.0	53.0	84.4	108.4	101.2	99.6
8	60.0	82.0	109.6	132.0	117.2	130.8

Subject 2

Trial	Task 2		Task 3		Task 4	
	1900	2000	2750	3000	3800	4000
1	61.0	45.0	53.0	42.0	102.0	98.0
2	60.0	58.0	32.0	55.0	90.0	88.0
3	46.0	81.0	26.0	53.0	101.0	103.0
4	66.0	66.0	50.0	38.0	83.0	92.0
5	55.0	50.0	62.0	75.0	90.0	119.0
6	41.0	23.0	71.0	52.0	108.0	130.0
7	50.0	45.0	56.0	41.0	96.0	130.0
8	50.0	81.0	100.0	35.0	84.0	137.0

PART III B

Subject 3

Trial	Task 2		Task 3		Task 4	
	1900	2000	2750	3000	3800	4000
1	86.4	100.8	69.6	153.0	102.8	102.4
2	119.2	114.8	141.0	124.0	104.4	95.2
3	104.8	127.6	161.0	122.0	109.6	106.8
4	78.8	134.8	160.0	174.0	98.0	98.8
5	102.0	98.0	184.0	146.0	98.4	117.2
6	123.6	92.8	203.0	158.0	100.4	103.2
7	122.8	130.8	166.0	222.0	105.2	109.6
8	128.8	126.8	206.0	207.0	91.6	100.4

Subject 4

Trial	Task 2		Task 3		Task 4	
	1900	2000	2750	3000	3800	4000
1	77.0	33.0	6.0	2.0	22.0	37.0
2	-4.0	129.0	2.8	-14.8	30.0	20.4
3	-2.0	118.0	14.4	10.8	18.4	23.2
4	33.0	-22.0	9.2	13.2	30.8	36.8
5	113.0	53.0	22.4	37.6	-12.4	24.4
6	-13.0	0.0	48.4	8.8	20.8	33.6
7	-9.0	-13.0	19.2	12.4	14.0	29.2
8	39.0	2.0	5.6	8.0	34.0	46.4

PART IV

BARTLETT'S TEST OF HOMOGENEITY OF VARIANCE

Subject	B/C
1	4.61
2	8.08
3	35.62*
4	34.60*

* Significant at the 5% level.

PART V

COEFFICIENT OF VARIATION (s_y / $\overline{Y}$ x 100%)

Subject	Task 2	Task 3	Task 4
1	18.6%	26.4%	21.6%
2	35.2	25.7	22.5
3	15.6	22.0	6.6
4	149.0	148.0	51.5

PART VI

PERSONAL DATA FOR SUBJECTS

Subject	Age	Weight	Height
1	23	152 lbs.	5 ft. 10 in.
2	20	140 lbs.	5 ft. $7\frac{1}{2}$ in.
3	24	175 lbs.	5 ft. 9 in.
4	28	160 lbs.	6 ft. 2 in.

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